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Heritage of Army Audiology and the Road Ahead: The Army Hearing Program

Noise-induced hearing loss has been documented as early as the 16th century, when a French surgeon, Ambroise Paré, wrote of the treatment of injuries sustained by firearms and described acoustic trauma in great detail. Even so, the protection of hearing would not be addressed for three more centuries, when the jet engine was invented and resulted in a long overdue whirlwind of policy development addressing the prevention of hearing loss.

We present a synopsis of hearing loss prevention in the US Army and describe the current Army Hearing Program, which aims to prevent noise-induced hearing loss in soldiers and to ensure their maximum combat effectiveness. (*Am J Public Health.* 2008;98:2167–2172. doi:10.2105/AJPH.2007.128504)

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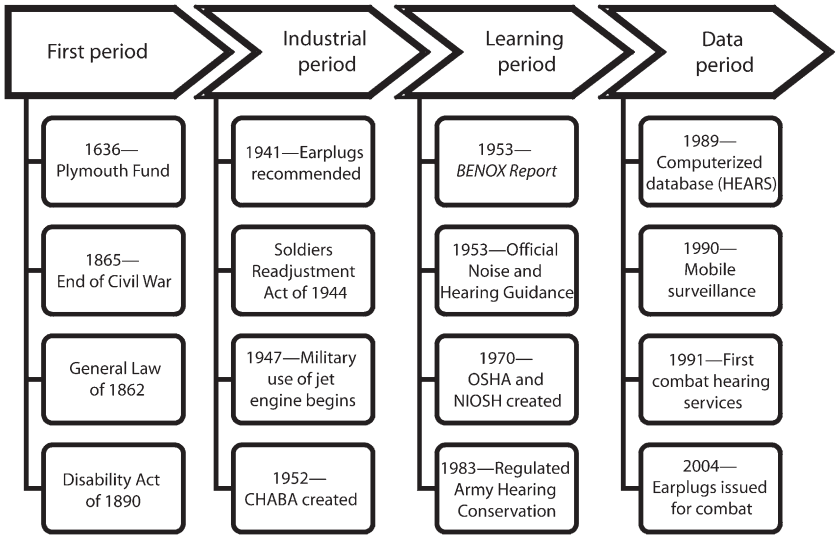
MILITARY CONFLICTS HAVE long been identified as a source of physical disability. Veterans' benefits were first documented in this country in 1636, when money was provided to individuals disabled in the Plymouth colony's defense.[1] Even before World War I, military veterans were receiving compensation for hearing loss. The medical records of Union Army soldiers document that 33% had diagnosed hearing loss.[2] Soldiers with disabilities from their military service were guaranteed a larger pension as compensation. Even though the method of measuring an individual's hearing acuity in the late 1800s is questionable by today's standards, hearing loss was recognized by the government as a disability. The General Law of 1862 and the Disability Act of 1890 were two major legislative movements that made this possible.[3]

Figure 1 delineates four distinct periods in the development of hearing loss prevention. There are specific developmental milestones in each period. These policies were the first of many seminal events that would influence the evolution of a program known as the Army Hearing Program; however, the road ahead would be full of challenges.

CHANGING ATTITUDES

In the period from the American Civil War to World War I, new occupational hazards evolved. One of the most prevalent of these was hazardous noise. The pervasive attitude of the early 1900s was that hearing loss could be prevented by developing a tolerance to noise. Consequently, any attempts to avoid loud sounds or to protect oneself from them were interpreted as weakness.[4] This "tolerance" theory was scientifically examined in 1941 when the US Army opened the Armored Medical Research Laboratory at Fort Knox, Kentucky. This laboratory completed a landmark study in 1944 resulting in the recommendation that gun crews, gunnery instructors, and others regularly exposed to gunfire blasts be provided hearing-protective devices. The hearing protector of choice was the V-51R, single-flange earplug.[5] Although hearing protection was now being considered, it still was not deemed a requirement.

Even though hearing conservation programs did not exist at the end of World War II, the army and navy surgeons general placed great emphasis on aural rehabilitation for veterans returning to their civilian lives. With the medical and administrative infrastructure not prepared to deal with the large numbers of veterans returning from war, Congress passed the Soldiers Readjustment Act of 1944 that made services more



Note. OSHA = Occupational Safety and Health Administration; NIOSH = National Institute for Occupational Safety and Health; CHABA = Armed Services Committee on Hearing and Bioacoustics; BENOX = Biological Effects of Noise Exploratory Study; HEARS = Hearing Evaluation and Reporting System.

FIGURE 1—Four distinct periods in the development of the Army Hearing Program.

available and efficient. This act reorganized the Veterans Administration (VA), which had been established in 1930 by combining the Veterans Bureau, the Bureau of Pensions, and the National Home for the Disabled Volunteer Soldier.[1] To further meet the great demand for aural rehabilitation services, many universities with audiology clinics also provided government-sponsored aural rehabilitation services for the veterans.

THE JET ENGINE

Even though World War II was a major contributing factor in the evolution of hearing conservation, it was not until after the war that the most significant event occurred. The Army Air Corps became a separate branch of service from the US Army and was renamed the US Air Force. Concurrently, this new branch of service introduced the jet engine aircraft to the military. No sound of that volume and duration had ever before been experienced. It was immediately noted that exposure to jet engine noise caused permanent hearing loss in a brief time. It also made verbal communication impossible and caused a series of physical manifestations described as "ultrasonic sickness." Symptoms included earache, headache, excessive fatigue, irritability, and feelings of fear.[6] Initially, it was believed that these symptoms were caused by inaudible, ultra-high-frequency sounds being generated by the jet engines. These symptoms, widely reported by air force maintenance crews, triggered a medical study that revealed that the illness was real; however, research attributed it to high levels of audible frequencies.[7]

As a result, the US Air Force published the first military regulation on hearing conservation in 1948. AFR 160-3, "Precautionary Measures Against Noise Hazards," is significant not only because it was the first enforceable regulation in the history of hearing conservation, but it also placed responsibility for the new program on the medical leadership at air force installations. Some of the preventive measures described in AFR 160-3 include limiting noise exposures in terms of overall sound levels and using cotton wads moistened with paraffin as hearing protection for exposures to hazardous noise.

In 1952, the Office of Naval Research reported the results of extensive interviews with hundreds of returning frontline soldiers who indicated that in combat, "sound was more important than all other means of equipment identification."[8(p20)] Combat-relevant sound sources included aircraft, mortar and artillery rounds, rifle and machine gunfire, and various other weapons. According to the report, "The men regarded the sound of enemy weapons as such an important means of identification that they rarely made use of captured equipment because it resulted in their being fired upon by friendly troops."[8(p20)]

QUEST FOR ANSWERS

During this same year, the navy requested a special investigation of noise hazards because of how near sailors were to jet engine noise on aircraft carriers. The report concluded that the effects of the loud sounds produced by jet engines were much greater and more serious than commonly assumed. These findings spurred the creation of the Armed Services Committee on Hearing and Bioacoustics (CHABA), which addressed the effects and control of noise, auditory discrimination, speech communications, and fundamental mechanisms of hearing and auditory standards.[6] This was the first major step to support the policy development for hearing-loss prevention. Immediately, CHABA commissioned a working group to study the effects of high-intensity noise on the human body. In December 1953, the results of this landmark study were released. The study was called the Biological Effects of Noise Exploratory Study but is referred to as the *BENOX Report*.[7] The report covered aural pain, hearing loss and protection, limiting factors for protecting the ear from noise, communication, orientation in space, and the psychological, neuropsychological, and central nervous system effects of noise.[7] It recommended, for the first time ever, monitoring for the prevention of noise-induced hearing loss as well as the establishment of a database to track hearing loss.

As a result of the *BENOX Report* and the wide dissemination of its results, prevention was

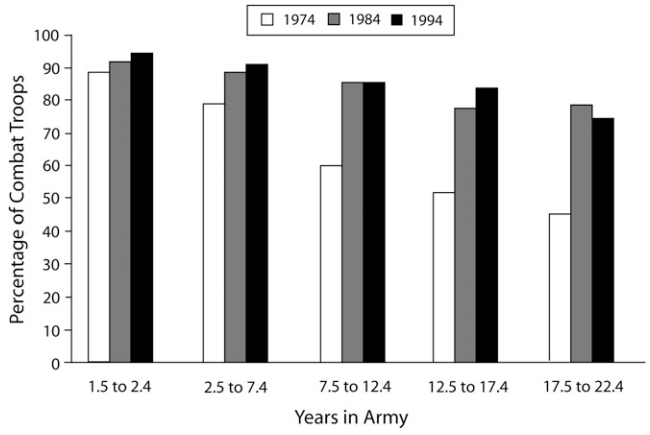


FIGURE 2—Percentage of combat troops with acceptable hearing, by length of time in the army.

considered the best solution to noise-induced hearing loss. The American Academy of Otology and Otolaryngology published the first written guide on hearing conservation outside of the military in 1953. Three years later, the army published Technical Medical Bulletin 251, "Noise and Conservation of Hearing." Even though this was the first step taken by the army to initiate a hearing conservation program, technical medical bulletins are not enforceable regulations and only are considered a guide based on standard practices. Later in the year, the air force renamed regulation AFR 160-3 "Hazardous Noise Exposure," and it became the basis of the first comprehensive hearing conservation program inside or outside the military. All of the essential components of a hearing conservation program by today's standards were included in this document.

ARMY AUDIOLOGISTS

Between 1965 and 1967, the army acquired its first six military audiologists. They were not used to implement and enforce hearing conservation standards, however, but instead worked in army medical centers performing clinical duties. It was not until 1970 that 25 additional army audiology positions were added to the inventory. These new audiologists spent only half of their time working in hearing conservation and the other half in the clinical setting; nevertheless, their impact was astounding. Figure 2 shows a significant decrease in hearing loss in the US Army over time that is directly attributable to the hearing conservation efforts of the new audiologists.[9–11] The data are broken down by length of time in service because of the often gradual nature and delayed onset of noise exposure.

These new army audiologists recognized that they were facing serious obstacles in implementing hearing conservation, including bureaucratic red tape, the lack of formal hearing conservation education in their audiology programs, a slowly changing military culture, and a lack of standardization of hearing conservation programs at individual installations. In 1968, to facilitate collegiality and professional development among military audiologists, an organization called the Military Audiology and Speech Pathology Society (now known as the Military Audiology Association) was formed. It was instrumental in the future of hearing conservation because it provided a foundation for the standardization of military hearing conservation programs and a way to mentor and educate audiologists with little or no hearing conservation experience.

MAJOR LEGISLATION

In 1970, the Federal Government enacted Public Law 91-596, the Occupational Safety and Health Act, which allowed for the creation of the Occupational Safety and Health Administration as the enforcement agency within the US Department of Labor.[12] The same year, the National Institute for Occupational Safety and Health (NIOSH) was created to develop criteria for safe occupational exposures to workplace hazards. In addition, the VA announced that it had paid over $52 million that year for hearing loss as a primary disability. That number did not include compensation for hearing loss with a concurrent disability or cost of hearing aids, batteries, or repairs. Further, the VA estimated that 20% of all veterans being discharged from the army were entering claims for hearing loss.[9]

In 1972, NIOSH published *Criteria for a Recommended Standard: Occupational Exposure to Noise*.[13] To reduce the risk of noise-induced hearing loss, NIOSH suggested a recommended equivalent level of 85 dB as an 8-hour time-weighted average, with a 5-dB exchange rate as well as methods for determining noise exposure.[6] The exchange rate is the rate at which sound energy is averaged over time and is often referred to as dose. If the intensity of an exposure increases by 5 dB, then the dose doubles. The dose of noise exposure determines how much time an individual can safely be exposed to hazardous noise. These standards would be an initial benchmark to hazardous exposure levels in the military.

Even with the quantifying of hazardous noise exposure and laws to enforce the standards, there was still no system in place to capture hearing conservation audiometric data and to measure compliance. In 1974, a new system for tracking hearing conservation compliance was being developed, the Hearing Evaluation and Reporting System (HEARS). (The name would later be changed to Hearing Evaluation Automated Registry System.)

A SCATHING INVESTIGATIVE REPORT

In 1976, the General Accounting Office (now the Government Accountability Office) released an investigative report on government working conditions.[13] It showed that more than half of US government employees—including those of the Department of Defense—were working in environments that did not have adequate procedures for identifying and rectifying occupational health hazards. Further, the report requested that Congress amend the Occupational Safety and Health Act to bring federal agencies under the inspection control of the Department of Labor.[13] As a result, military audiologists and other government employees achieved standardization in

TABLE 1—Incidence of Diagnosed Noise-Induced Hearing Loss in the US Army: April 1, 2003, to March 31, 2004

Condition Diagnosed	No. of Postdeployment Troops (n = 806), %	No. of Nondeployed Troops (n = 141 050), %
Acoustic trauma	45 (5.6)	78 (0.1)
Permanent threshold shift	236 (29.3)	639 (0.5)
Tinnitus	248 (30.8)	2101 (1.5)
Eardrum perforation	13 (1.6)	88 (0.1)
Moderately severe hearing loss or worse	127 (15.8)	3140 (2.2)
Any of the above	553 (58.6)	5668 (4.0)

Note. Postdeployment troops are soldiers who had recently returned from active duty in Iraq or Afghanistan; nondeployed troops are soldiers who had not served in combat.

military hearing conservation in 1978 with the publication of Department of Defense Instruction (DODI) 6055.12. This document provided guidance and requirements for implementing hearing conservation.[14]

To implement DODI 6055.12, the army published TB MED 501, *Hearing Conservation*, in 1980. DODI 6055.12 was updated in 1987 to implement new requirements by the 1983 Federal Noise Amendment.[15] The new policy identified specific roles and responsibilities within a hearing conservation program and thereby paved the way for the first enforceable regulation to be published on the subject in the US Army. This new implementing document was called Department of the Army Pamphlet 40-501, *Hearing Conservation Program*.

AUTOMATION AND MOBILITY

In the same decade that the Internet was introduced to the public, the military's goal of computer-automated data capture became a reality. In 1989, the Occupational Health Management Information System provided funding for the development and distribution of HEARS by the US Army Environmental Hygiene Agency.

In 1990, an effort was made to increase compliance of occupational health screening by combining the services into a mobile vehicle called the military occupational health vehicle (MOHV). Subsequently, the army purchased 16 of them for use worldwide. This development facilitated the promotion of the newly developed HEARS by taking the monitoring equipment and services to the soldiers, a convenience that commanders favored. Although comprehensive occupational health screenings were the goal, the MOHV was primarily used for hearing monitoring, the other health services preferring that screenings be conducted in a fixed facility.

By January 1991, over half a million allied troops were deployed in Saudi Arabia and throughout the Gulf region to liberate Kuwait from the Iraqi invasion. The allied armies launched the ground war on February 23; by March 31, Iraq accepted the terms of a ceasefire and the allied troops began to be sent home. To facilitate the redeployment of US soldiers back to the United States, 11 army audiologists were sent to Saudi Arabia with 11 MOHVs. During the 2-month redeployment process, 29 192 hearing screenings and 5254 comprehensive audiometric follow-up evaluations were conducted. A manpower resource model estimated that 82 weeks (3280 work hours) of postdeployment audiometric evaluations were saved by providing the service in Kuwait while the soldiers waited to fly home.[16] This program was a success because many of the units deployed were reserve and national guard forces and would not have ready access to audiological services once they returned to civilian life. Unfortunately, funding for the MOHV concept was not sustained after the military drawdown of the early 1990s.

In 1998, HEARS was upgraded to include an online portal for submitting hearing conservation data. The new system, called the Defense Occupational Environmental Health Readiness System for Hearing Conservation (DOEHRS-HC), made accessing data faster and significantly less laborious. In an attempt to increase compliance, Department of the Army Pamphlet 40-501 was updated to state that monitoring of hearing conservation was to be conducted with DOEHRS-HC.

All of the hearing conservation efforts of the past have led to significant improvements in levels of hearing loss in the army and are a direct result of army audiologists' influence on program compliance. Acceptable hearing is defined as when the pure tone average (500 Hz, 1000 Hz, and 2000 Hz) is no worse than 30 dB in each ear, with no individual

TABLE 2—Effect of Tank Crewmen's Ability to Understand Spoken Orders on Their Performance in Combat Situations in the US Army

Task	Good Word Intelligibility	Poor Word Intelligibility
Time required to identify target, seconds	40	90
Incorrect command heard, %	1	37
Correct target identification, %	98	68
Correct targets engaged, %	94	41
Incorrect target engaged, %	0	8

Source. References 9 and 21.
Note. "Good word intelligibility" means understanding 50% or more of what was said to them; "poor word intelligibility" means understanding less than 50%.

threshold greater than 35 dB and thresholds not exceeding 55 dB at 4000 Hz.

ARMED CONFLICT AND HEARING LOSS

Whether in peacetime or wartime, hazardous noise is one of the primary occupational hazards in the army, and the risk of soldiers incurring noise-induced hearing loss is greater than it has been in over 30 years. This is a result of current combat operations, increased numbers of combat soldiers, extended periods of weapons training, and the deployment of new and more powerful noise sources from weapons systems, vehicles, and aircraft. US forces in Iraq and Afghanistan have experienced a substantial number of blast injuries from improvised explosive devices, rocket-propelled grenades, and mortar rounds. These types of explosions remain the single largest cause of injury in the war in Iraq (Operation Iraqi Freedom) and compose 47% of all medical evacuations.[17] As a result, developments in protecting soldiers from these types of hazards are paramount.

The combat arms earplug was introduced into the military at the start of the war in Afghanistan (Operation Enduring Freedom). However, as with most hearing protection, it was shunned for operational use and, at approximately $6.00 per pair, was considered prohibitively expensive by individual army units. The device allows soft sounds to flow unimpeded through a filter but blocks loud impulse sounds, such as an explosion or a rifle discharging. This allows effective communication, enables situational awareness, and provides protection from hazardous weapons firing and explosions. With units' strength decreasing because of hearing loss, commanders began to recognize that hearing readiness is an extremely important factor of a unit's performance in combat. All deploying soldiers were therefore issued the earplugs in 2004. In fact, the US Marine Corps was so convinced of the effectiveness of the combat arms earplug that it ordered over 20 000 pairs, thereby temporarily depleting the entire national stock in 2003.[17]

AUDIOLOGY IN IRAQ

During the first year of the war in Iraq, an average of one soldier a day was medically evacuated for complaints related to hearing loss. Consequently, recommendations were made in October 2003 for an audiology support program that would use a minimum of 9 hearing conservation technicians assigned to locations of dense troop population. To curb the need for medically redeploying soldiers, it was recommended that one army audiologist serve as a consultant, examine follow-up patients, assign duty limitations, dispense hearing aids, verify threshold shifts, and evaluate any possible pathology identified by the hearing monitoring. Initially, only one audiologist with no support staff was authorized, who used old equipment that had been donated by a clinic in Landstuhl, Germany.[18] By 2006, new audiology equipment had been acquired; by 2007, five outlying screening sites had been established.

Also during the first year of the Iraq war, a study was conducted in army medical facilities comparing hearing loss among soldiers who had been exposed to combat in Afghanistan or Iraq and among those who had not.[19] As shown in Table 1, soldiers who had served in combat had significantly higher rates of hearing loss than did those who had not served in combat.

THE ARMY HEARING PROGRAM

Providing these reactive audiology services in a combat zone was logical, but the concept was not wholly sound, because it negated the need for maintenance of soldiers' hearing readiness while in a combat environment. The hearing conservation paradigm had shifted, and it now had to consider the soldiers on the battlefield. As a result, a restructuring occurred, and a contemporary model called the Army Hearing Program was born.

The Army Hearing Program is charged with preventing noise-induced hearing loss in soldiers and ensuring their maximum combat effectiveness in training as well as during deployments. To accomplish this mission, four pillars of service were established: operational hearing services, hearing conservation, clinical services, and hearing readiness. The program aims to maintain a high state of readiness and to protect hearing without compromising the effectiveness of the soldier.

HEARING AND PERFORMANCE

A study evaluating the importance of hearing for soldiers in combat was conducted at the US Army Human Engineering Laboratory, which investigated the impact of noise and other variables on the mission effectiveness of tank crews.[20] The study found that a crewman's ability to understand verbal orders influenced their response times as well as their performance of specific tasks. As shown in Table 2, poor understanding led to slower response times, which can mean the difference between life and death on the battlefield. Communication in a tactical environment is of utmost importance.

The problem of protecting hearing while enhancing soldiers' communication ability and situational awareness was solved with a new generation of hearing protection. This new category of equipment was called tactical communications and protective systems (TCAPS). In 2007, TCAPS were introduced into the army as a possible solution to an age-old problem. TCAPS compose a new category of electronic hearing protection that uses active noise reduction to soften noise and enhance speech discrimination while at the same time reducing noise by up to 40 dB. In addition to being light and rugged, TCAPS provide protection and let soldiers monitor environmental sounds, communicate, accurately gauge auditory distance, and localize sound sources without hindrance. Further, the devices allow radio connections specifically used by the military to be processed without interrupting the signal when the TCAPS are actively blocking environmental sounds. Although this category of device is still being studied and protocols for use are being created, it represents a new era in the history of hearing protection.

STRONG ARGUMENTS

With hearing conservation programs documenting marked initial improvements, the anticipated cost of veterans' disability claims and payments were expected to decrease over time.[10,11] However, with the start of the war in Afghanistan in 2001 and the war in Iraq in 2003, this proved not to be the case. Current data show

that 51.8% of combat soldiers have moderately severe hearing loss or worse,[21] mainly because of the loud sounds associated with combat. The implications for the army are great. When soldiers reach these levels of hearing loss, they must be evaluated for the ability to perform their duties safely and effectively. Depending on the findings, they may be given the option of changing to a job that does not put their hearing at further risk or leaving the service with a medical discharge. In light of this, 10 much-needed army audiology positions were added in 2007. These positions will have a positive impact on the Army Hearing Program, but there will still be only two thirds as many army audiologists as there were before the military drawdown of the early 1990s. Still, with war, there are some injuries related to noise-induced hearing loss that cannot easily be prevented, such as traumatic brain injury, dizziness, auditory neuropathy, and central auditory processing disorders. Evaluation and management of these injuries are also within the scope of the practice of audiologists and further strengthen the need for adding more military audiology accessions to support the war effort.

In 2006, the number of new applicants granted primary disabilities for hearing loss and tinnitus was 49 606 and 61 269, respectively. Combined, the total disability payments for hearing loss and tinnitus were over $1 billion, marking a 319% increase since the beginning of the war in Afghanistan in 2001. Tinnitus was responsible for the largest number of primary disabilities in 2007, followed closely by hearing loss.[22] To complicate matters, the average process time for applying for hearing-loss disability by veterans in 2007 was 789 days,[23] showing the need to improve the entitlement process. Prevention, however, is still the best answer not only from a cost-benefit standpoint but for the quality of the lives of veterans and their families. The Army Hearing Program represents a means to eliminate hearing loss as a result of battlefield conditions in the 21st century. ■

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Contributors

D. S. McIlwain originated the topic, wrote most of the essay, and led and supervised the literature review and analyses of information in this essay. K. Gates and D. Ciliax wrote significant portions of the essay, assisted in analyses, and provided editorial support.

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